CENTAURUS A - SOURCE POPULATIONS IN THE NEAREST BRIGHT ELLIPTICAL

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Final Report

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The XMM/Newton observations of the nearby radio galaxy, Centaurus A, have proven to be a rich data set and has given us new insights into several important processes present in Centaurus A. A list of publications, conference proceedings, and conference abstracts related to these data are attached at the end of this document.

We have used the XMM/Newton observations to study the interaction between the relativistic, radio emitting plasma emitted from active nuclei with the hot interstellar medium. Centaurus A is the nearest radio galaxy, so that we have been able to study these features at a linear resolution unattainable for any similar object. Data from the EPIC cameras was used to determine the temperature and radial surface brightness profile of the hot ISM. Beyond the central 2 kpc region where variable absorption by the intervening dust lane complicates analysis, we find the temperature of the gas to be isothermal with radius with a temperature of 0.29 keV. The temperature and luminosity of Cen A was found to be consistent with that derived for other early galaxies of similar optical luminosity.

An X-ray enhancement was detected along the boundary of the SW radio. Based on the morphology and spectrum of this enhancement, we rejected a variety of non-thermal (i.e. synchrotron or inverse-Compton scattering) models for the origin of this emission. We concluded that it is most likely that this X-ray enhancement is due to a shell or cap of shock heated gas surrounding the SW radio lobe. The supersonic expansion of the lobe into the ISM heated the gas created this shell. The result has several important implications. Interestingly, the thermal energy of this shock heated shell is a significant fraction of the thermal energy of the hot ISM within 10 kpc of the nucleus. This suggests that radio activity can provide enough energy to reheat the ISM of early galaxies, and perhaps clusters of galaxies by extension, and prevent the formation of massive cooling flows. The pressure of the shell is an order of magnitude greater than the equipartition pressure of the radio lobe. This demonstrates that the pressure of the lobe must be dominated by unseen particles, most likely either a population of lower energy (but still relativistic) electrons or by energetic protons.

In addition to studying the diffuse emission, we have used data from the EPIC cameras to study the spectrum and temporal variability of the X-ray emission from the nucleus. Analysis of this data has proven to be a considerable challenge because of the very high rate (20+ cts/s in the PN camera) and consequent pile-up. We resolved the problem of pileup by considering only events in an annular region in the wings of the PSF of the nucleus. In order to model the spectrum of the nucleus, we had to subtract off the contribution from the thermal galactic emission and from the jet with the PSF of the nucleus. We used data from our Chandra/ACIS-I observations to determine the spectrum and normalization of these components to use as a 'background' for the XMM/Newton observations. We found that the nuclear spectrum is well described by a heavily absorbed power law model with an Fe K line whose energy is consistent with neutral material. The equivalent width of this line is consistent with absorption and re-emission from neutral material in a disk around the central black hole with a small covering factor. This line is unresolved in the XMM/Newton data (although we have resolved with our Chandra/HETG observations). We have also detected small (<20%) temporal fluctuations in the nuclear flux on the timescales of thousands of seconds.

Analysis on the RGS spectrum of the hot ISM in the central region and on the X-ray point source population is ongoing.

Publications related to these observations:

Refereed Papers

- R. P. Kraft, et al. 2003, 'The X-ray Spectrum of the Nucleus of Centaurus A', in preparation.

- R. P. Kraft, et al. 2003, 'X-Ray Emission from the Hot Interstellar Medium and Southwest Radio Lobe of the Nearby Radio Galaxy Centaurus A', Ap. J., 592, 129.

Conference Proceedings

- R. P. Kraft, et al. 2003, 'High Resolution X-ray Observation and Monitoring of the X-ray Jet and Radio Lobes of Centaurus A', Proceedings of the 'Physics of Relativistic Jets in the Chandra and XMM/Newton Era' Conference, New Astronomy Reviews, in press.

Conference Abstracts

- D. Evans, et al. 2003, 'XMM/Newston and Chandra/HETG Observations of the Spectrum of the Nucleus of Centaurus A', Four Years of Science with Chandra Symposium.

- D. Evans, et al. 2003, 'The XMM/Newton X-ray Spectrum of the Nucleus of Centaurus A', United Kingdom National Astronomy Meeting.

- D. Worrall, et al. 2003, 'X-ray and Optical Properties of Radio Jets', IAU Symposium 218.

- S. Vazquez, et al. 2001, 'Preliminary Results from an XMM-Newton Observation of the Nearby Radio Galaxy Centaurus A', BAAS, 199, 51.03.

- R. P. Kraft, et al. 2001, 'Chandra Observations of X-ray Emission from the Radio Lobes of Centaurus A: Indirect Evidence of a Counterjet?', Two Years of Science with Chandra Symposium.